



State of Utah
DEPARTMENT OF HEALTH
DIVISION OF ENVIRONMENTAL HEALTH

Ref D

Norman H. Bangert
Governor

Suzanne Dandoy, M.D., M.P.H.
Executive Director

Kenneth L. Alkema
Director

288 North 1460 West
P.O. Box 16690
Salt Lake City, Utah 84116-0690
(801) 538-6121

March 30, 1989

Mr. Ed King
Jumbo Mining Co.
6305 Fern Spring Cove
Austin, TX 78730

Re: Jumbo Mine
Authorization to Operate

Dear Mr. King:

Based on the information submitted earlier and information received in a phone conversation of 23 March 1989, Jumbo Mining is hereby authorized to operate the authorized pads i.e. #1, #2, #3, #4, and #5; subject to the following conditions:

1. A proposal for removal of ore from any pad, including the minimum amount of ore which will remain to protect the liner, must be submitted for review and approval.
2. Cyanide will only be applied to ore which is resting upon an approved lined heap leach pad.

Please contact Charlie Dietz or Mack Croft if there are any questions.

Sincerely,

Utah Water Pollution Control Committee

Don A. Ostler, P.E.
Executive Secretary

CGD/ag

cc: Bruce Hall, central Utah District Health Department, Nephi
Lowell Braxton, Division of Oil, Gas and Mining

4076y-90

Soil Moisture Content. The soil samples were air dried and screened on a 30 mesh sieve prior to using them in the various cyanide attenuation tests. Following the air drying the soil moistures were measured at least two times and the results were averaged. These measurements are presented below.

Soil	% H ₂ O	% H ₂ O	Avg H ₂ O
Thunder Mt., Top Soil	3.1	2.2	2.6
Thunder Mt., Green Clay	2.5	2.5	2.5
Barrick, Leach Area #2	2.3	2.3	2.3
Montana Tunnel, Colluvium	1.7	1.8	1.7

Soil pH. The soil pH of the soils tested ranged from as high as 9.55 to 5.50. In almost every case the soil pH results were lower than the final pH measured in the sealed stirred reactor with that specific soil. The final pH measured in the sealed stirred reactor ranged from 9.4 to 6.4. These slightly higher pH results were not unexpected since the pH of the cyanide solution added to the stirred reactor was about 10 versus the pH of the deionized water at 6.7. The pH results of the stirred reactor and deionized water tests are presented in Table 3.

TABLE 3

pH Results of Stirred Reactor
and Deionized Water Tests

Soil	pH-Deionized Water ¹	pH-Stirred Reactor ² (initial-final)
Barrick Manning Shale	9.55	10.1-9.4
Barrick Dump Leach #1	8.94	10.2-9.2 <i>In Calc</i>
Barrick Dump Leach #2	9.08	9.97-9.31 <i>7.4</i>
Thunder Mountain Top Soil	5.80	10.3-7.5
Rochester	9.16	10.3-9.4
Carlin Overflow	8.62	10.2-9.3
Montana Tunnels Colluvium	6.67	9.97-8.6
Delamar Meadow	5.50	10.1-6.4
Western Goldfields	7.46	10.3-7.5

¹The deionized water test was conducted by placing 10 grams in 100 ml of deionized water and measuring the pH after 10 minutes. The initial pH of the water was 6.7.

²The stirred reactor tests lasted approximately 30 hours each, in which 100 grams of soil was placed in one liter of solution containing 26 ppm of free cyanide.

Stirred Reactor Tests

Soils. The equipment and procedures for the stirred reactor tests are described above. All stirred reactor tests were sealed and performed with one liter of cyanide solution unless otherwise noted. The results of these tests are presented in Table 4. The test results of three soils that exhibited good cyanide attenuation are presented in Figure 3.

Pure Component Tests. Sealed stirred reactor tests were conducted with 100 grams of potassium feldspar, plagioclase (calcium feldspar), bauxite, kaolinite and organic matter (2) in a one-liter 10⁻³M cyanide solution. The initial solution pH's were 10.3. In 24 hours, the potassium feldspar attenuated 8% of the cyanide and the plagioclase (calcium feldspar) attenuated 6% of the cyanide. The results of these tests are presented in Figure 4. The final solution pH was 9.88 and 10.0, respectively.

A second stirred reactor test was conducted with one liter of 10⁻³M CN⁻ (49 mg/l NaCN) solution and 200 grams of plagioclase. The initial solution pH was 10.4. In this test CO₂-free argon gas was passed over the reactor. In the second test 7% of the cyanide was collected in the gas trap. An additional 83% of the cyanide remained in solution. This indicates that 10% of the cyanide was attenuated by the soil in 24 hours. A total cyanide analysis was performed on the solution-plagioclase mixture following the test completion. About 86% of the original cyanide content was detected in the total cyanide test. Given some analytical error, total cyanide roughly equaled free cyanide for this test; hence, little if any cyanide-metal complexes were present in the solution.

Sealed stirred reactor tests were conducted with 100 grams of bauxite and kaolinite in a one-liter 10⁻³M cyanide solution. In 24 hours, the bauxite attenuated 24% and the kaolinite attenuated 27% of the cyanide. The test results indicate that bauxite and kaolinite have significant cyanide attenuation abilities. The results of these tests are contained in Figure 4. The final solution pH's were 6.2 and 8.64, respectively.

The final solution was analyzed for total cyanide, which showed significantly variations from the reported free cyanide content of the solution. It is suspected that aluminum is causing interference with the analyses. Further studies in these systems are required.

Two sealed stirred reactor tests (Tests A & B) were conducted with 100 grams of organic matter (compost) in a one-liter 10⁻³M cyanide solution. The material for Test A was partially decomposed compost. Conversely, the Test B material was completely decomposed. The initial solution pH's were 10.0 and 9.7, respectively. The decomposed organic matter outperformed the partially decomposed material in the tests. In 9 hours for Test B, 38% of the cyanide was

degradation

Towill et al.¹⁹ reported that cyanide salts move only a short distance through soil before being biologically converted under aerobic conditions to nitrates (microbial degradation to NH_3 , then conversion to NO_3^- or fixed by trace metals through chelation. The vast majority of this attenuation was attributed to biodegradation. Strobel²⁰ tested both sterile and non-sterile soils to determine their effect on cyanide. The non-sterile soil degraded cyanide, while the sterile soil did not appreciably alter cyanide. Fuller⁷ reported that cyanide up to 200 ppm was readily converted to fertilizer nitrogen in the soil. In fact, plants responded to cyanide applications nearly identically as they did to sodium or ammonium nitrate.

Cyanide biodegradation is currently being utilized to treat industrial wastewater in two separate processes. Homestake Mining Co. uses bacteria to treat its wastewater prior to discharge. ICI Bioproducts detoxifies cyanide with a strain of the fungus *Fusarium lateritium*. Experimentation is proceeding with strains of augmented natural bacteria to treat cyanide contaminated groundwater.

Biodegradation under anaerobic conditions is not nearly as prolific as aerobic. The limit for effective anaerobic degradation of cyanide was found by Coburn²¹ to be 2 ppm. Above this concentration, the cyanide was found to be toxic to the anaerobic microorganisms.

SOIL CHARACTERIZATION

Since specific soil constituents demonstrate significant cyanide attenuation, soil characterization has been an essential portion of the testing procedure. Twenty eight different soil types from sites located in eight different western states have been characterized and tested. Most of these soils have been analyzed for mineralogy (x-ray diffraction), organic carbon, soil pH and soil texture. The results of the tests are presented below.

Mineralogy

The mineralogy of the samples was determined by x-ray diffraction.

The mineralogy results are listed in Table 1. The main mineralogical difference between the various soils are the levels of quartz, feldspars and clays products found in the samples. Since the quartz showed little reactivity with the cyanide, the feldspar and clay minerals have been of most interest. The soil samples contained between 7 and 30% feldspars (orthoclase and plagioclase) and approximately 30-50% clay minerals (mainly kaolin, illite and smectite). From pure component testing, the feldspars have been found to react with cyanide by both releasing metal ions that chelated with the cyanide and by adsorbing the cyanide and acting as an oxidizing site to cyanate. The cyanide oxidation was enhanced in the presence of copper ions. Smectite also adsorbed cyanide. The pure smectite sample that was tested exhibited no release of metals or cyanide complexes.

Organic Carbon Content

The organic carbon analyses were performed using the Walkley - Black methodology. The results of these tests are listed in Table 2. The arid western U. S. soils and subsoils tested averaged about 0.6% organic carbon with a range from 0.3 to 2.17%. These values are on the low range of carbon content for typical U. S. soils, which averages about 2%.

Organic carbon was measured as a function of depth for two holes at the site in Nevada. The organic carbon content decreased with depth. The carbon content at 2½ ft. below the surface averaged 0.6% and it reduced with depth to 0.25% at 25 ft. Four soil samples between 25 and 55 ft. (the bottom of the hole) averaged 0.25% organic carbon.

Soil pH

Soil pH was measured at the Utah State University and the data are given in Table 2. All of the soils tested exhibit natural pH below the pK of cyanide (9.36) where the HCN and CN^- values are equal. A plot of the relationship of HCN and CN^- with pH is presented in Figure 1. This plot shows that if the cyanide solution in the soil was at a pH of 8.0, about 95.6% of the free cyanide would be in the form of HCN . At

Table 1
Soil Mineralogy

Approximate Weight Percent Mineral Constituents in Soil

Soil Sample	Crstblt	Qtz	Plagio	KSpAr	Calcite	Dolomite	Amphble	Hema	Pyrt	Halloy	Kaoln	Chlor	Illit	Smctit	Pyro	Clinpt	Other ¹
BTS	-	50	-	2	23	14	-	-	-	-	3	-	2	27	-	-	4
BC	-	39	7	6	17	-	-	17	-	-	-	3	6	33	-	-	4
ED	-	16	14	9	10	-	1	17	-	-	-	-	5	27	-	-	43
C	-	14	11	10	2	-	-	-	-	1	-	-	9	52	-	17	-
CC1	-	22	19	9	2	-	-	17	-	-	-	2	8	13	-	17	23
CC2	-	27	21	11	2	-	3	17	-	-	-	-	9	8	-	-	13
F1	-	51	7	5	3	-	-	-	17	-	2	-	18	27	-	-	8
F2	-	55	10	6	-	-	-	-	-	-	2	-	18	27	-	-	8
GS	-	27	10	15	10	-	17	-	-	-	-	17	7	15	-	6	8
BH	-	19	7	4	23	-	1	-	17	-	-	-	4	27	-	17	36
G	-	6	23	5	4	-	-	3	-	1	-	-	-	53	-	-	5
WGF	13	9	11	6	-	-	-	-	17	-	5	-	3	18	-	-	45
USP	-	7	7	4	8	-	-	-	-	-	-	2	7	7	-	-	57
H2	-	9	9	5	4	-	-	-	-	-	-	-	12	13	14	31	-
HMS	-	27	-	-	-	-	-	-	-	-	2	-	6	7	-	-	-
BD2	-	28	8	5	34	-	-	-	1	-	2	-	4	6	-	-	-
B1	-	35	6	3	43	-	-	-	1	-	2	-	3	19	5	-	-
H1	-	34	20	8	9	-	-	-	17	-	1	3	19	5	-	-	-
R	-	23	19	8	17	-	17	-	-	-	-	-	5	9	-	-	33
TMTS	25	21	-	262	-	-	-	-	17	-	-	-	17	7	-	-	19
THC	-	41	9	15	-	-	-	-	-	-	-	-	13	2	-	-	20
6	-	15	25	3	-	-	-	-	-	-	2	-	5	23	-	-	21
5	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	7	15
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7

Notes:

Other¹ - Amorphous, below detection limit, could include glass opal, amorphous clay, organic material.
K-Spar² - Sanidine; all other apparently orthoclase.

Crstblt - Cristobalite	Qtz - Quartz	Plagio - Plagioclase	KSpAr - K-Feldspar
Dolomite - Dolomite	Amphble - Amphibole	Hema - Hematite	Pyrt - Pyrite
Halloy - Halloysite (7 Å)	Kaoln - Kaolin	Chlor - Chlorite & Kaolin	Illit - Illite & Mica
Smctit - Smectite	Pyro - Pyrophyllite	Clinpt - Clinoptilolite	

Table 2
Soil Characteristics

Soil	Soil pH	Org Matl	CEC	Elect Cond	Percentage			Texture
					Sand	Silt	Clay	
HM1	8.5	0.26	19.0	0.4	87	8	5	Loamy Sand
HM2	7.7	2.17	26.7	2.4	36	48	16	Loam
CA	8.0	.26	9.3	0.2	88	6	6	Sand
B2	8.0	.7	-	-	36	57	13	Loam
MT	6.8	1.1	-	-	66	28	7	Sandy Loam
TMTS	4.5	1.0	-	-	32	55	13	Loam
N	7.2	0.3	-	-	-	-	-	-
N1	7.4	0.1	-	-	60	24	16	Sandy Loam
WGP	6.7	1.2	-	-	-	-	-	-
THOC	-	0.1	-	-	32	48	20	Loam
CC1	8.3	0.5	-	-	-	-	-	-
CC2	8.2	.62	19.7	4.3	43	46	11	Sandy Loam
BN	8.2	1.34	16.1	0.5	37	36	27	Loam
C	7.4	0.28	43.6	5.3	33	23	44	Clay
N2	7.3	0.48	13.0	25.5	60	24	16	Sandy Loam
CS	7.7	0.55	18.4	2.0	57	26	17	Sandy Loam
ZE	7.9	0.52	11.6	23.0	76	13	11	Sandy Loam
P1	5.8	0.86	13.5	0.3	50	31	19	Loam
P2	5.8	0.89	12.4	0.3	44	33	21	Loam
RM	8.6	0.86	16.2	5.7	75	13	12	Sandy Loam
CUS	8.9	0.3	2.6	3.2	62	8	30	Sandy Clay Loam
BTS	7.9	0.67	-	-	48	35	17	Loam
AC	7.1	1.19	-	-	11	58	31	Silty Clay Loam
CSF	7.6	0.74	-	-	68	22	10	Sandy Loam
C	8.3	0.66	-	-	31	21	48	Clay

a pH of 7.6, about 98.3% would be HCN.

Hence, if there is a pathway to the atmosphere by which gaseous hydrogen cyanide may escape, volatilization could be a significant degradation mechanism in these soils. In addition to HCN volatilizing and diffusion out of the soil, it was found that HCN is more active in adsorbing on soil surfaces than CN^- - either in the solution or in the gas phase, which is typical of many other organic acids.

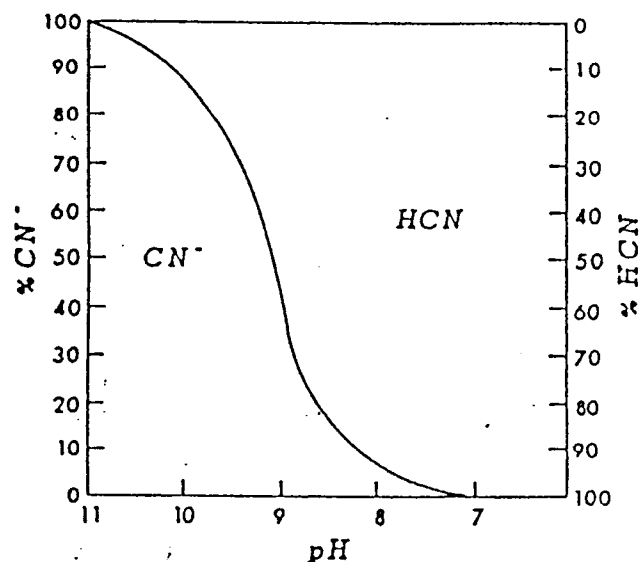


Figure 1
Dissociation of Hydrogen Cyanide
as a Function of pH

TEST RESULTS

Kinetic Reactor Tests - Pure Minerals

There are three different types of surfaces responsible for adsorbing anions such as CN^- in soil. The first is oxide surfaces, such as Fe or Al, that form oxides and surface hydroxyl groups (OH). The M-OH is in equilibrium with soil water or groundwater. Depending upon the pH of the soil system, M-OH can develop either a positive or negative charge. If the pH is high, then M-OH will develop a negative surface charge due to H^+ dissociation from the OH group. If the pH is low, then M-OH will develop a positive surface charge by attracting H^+ . Hence, the surface charge of oxides is pH-dependent. For example, goethite ($\alpha\text{-FeOOH}$) possesses a net negative charge above a pH of

approximately 8.5 and adsorbs cations. However, goethite possesses a net positive charge below a pH of approximately 8.5 and adsorbs anions.

The second type of surface responsible for attracting and accumulating anions is the edges of aluminosilicate clay minerals. The edges of these minerals contain ions that are not fully coordinated. As a result, these edges adsorb H^+ and OH^- to form hydroxylated surfaces and behave in a manner similar to metal oxides. Since all clay minerals have edges, they all participate to some extent in adsorbing anions. However, the 2:1 clay miners (smectite) have edges that comprise only about 1% of the total surface charge; therefore, these minerals do not extensively adsorb anions. On the other hand, the 1:1 clay mineral (kaolin) edges comprise a relatively greater proportion of the total surface charge; as a result, these minerals can adsorb a relatively greater percentage of anions.

The third type of surface responsible for attracting and accumulating anions in soils is organic matter. Soil organic matter possesses functional groups that adsorb H^+ and OH^- to form charged surfaces and behave in a manner similar to metal oxides. All three of these surfaces have been found to adsorb cyanide in these tests.

The kinetic reactor test results for plagioclase, orthoclase and kaolin were performed in stirred reactors. Orthoclase (K-feldspar), plagioclase (Ca-feldspar), and kaolin all adsorb followed by oxidation to cyanate. A mathematical model was developed to fit the experimental data. This model was used to predict the adsorption - oxidation of cyanide on the various pulp densities of orthoclase, plagioclase and kaolin minerals. A typical example for orthoclase is shown in Figure 2. The calculated curves predict the experimental data points well for the 100 g/l and 200 g/l pulp densities. However, for the 400 g/l pulp density, the calculated values are greater than the experimental. This variation may be due to interaction of the soil particles or insufficient stirring at the higher pulp densities.

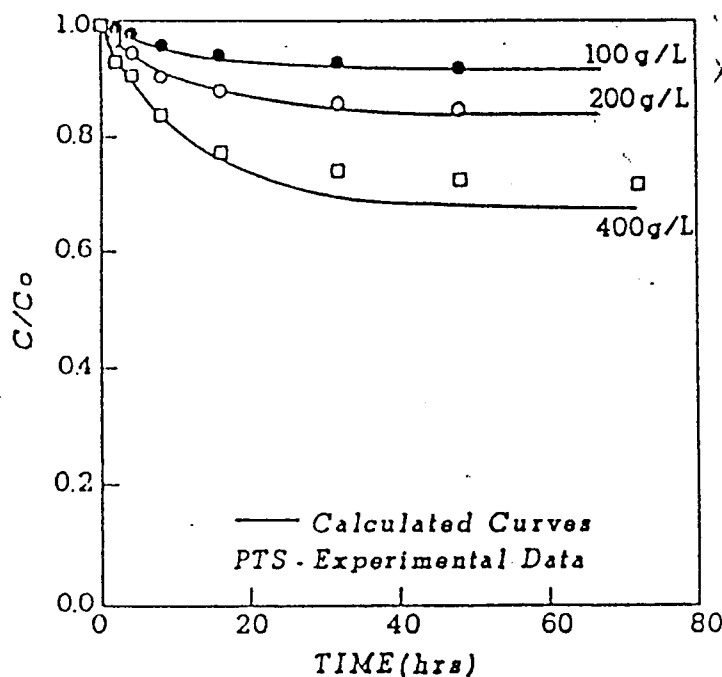


Figure 2
Predicted and Measured Cyanide Removal
in Orthoclase-Cyanide Pulp

These reaction models suggest that the feldspars and kaolin clay may remove as much as 0.05 mg of cyanide per gram of mineral. The impact that this mechanism might have on a cyanide release in a typical arid soil with average feldspar (orthoclase and plagioclase) content of 20%, a density of 100 lb/ft³ and a porosity of 40% is estimated below. If one pore volume of 130 ppm cyanide solution passing through a foot of soil interacts with 25% of the feldspar, it

Ref (6)

Copy given Mach Craft
8/10/89SOUTHERN UTAH STATE TESTING LAB
SCIENCE BLDG. - ROOM 010
351 WEST CENTER
CEDAR CITY, UT 84720

SAMPLE NUMBER : K0890515

COST : 154.20

TIME COLLECTED : 10:00 AM

DATE COLLECTED : 5-22-89

DATE RECEIVED : 30-MAY-1989

DATE COMPLETED : 5-JUL-1989

DATE SENT : 7-27-89

INVOICE NUMBER : G-K0890515

COLLECTOR : DAVE HASLOW

SITE LOCATION : BUSBY SPRING

SEND RESULTS TO : JUMBO MINING COMPANY
P.O. BOX 999
DELTA, UT 84624

ANIONS CATIONS CATIONS GEN PRAM OXYGEN CHECKS

195.7 BICAR

* 1.34 Fe-T

< 0.01 Pb

* 878.0 Cl

0.004 As

39.9 Mg

< 0.1 Ba

* 0.272 Mn

0.42 FLUCR

<0.001 Hg

7.8 PH

* 49.20 NO3

<0.002 Cd

5. K

< 0.40 SURF

393.0 Ca

<0.005 Se

<0.005 Ag

< 0.01 Cr

445.0 Na

* 2568. TDS

0.03 Cu

0.10 Zn

189.00 TURBI

423.0 SO4

NOTES :

Ref (7)

Copy faxed to Mach Gaf
8/14/89SOUTHERN UTAH STATE TESTING LAB
SCIENCE BLDG. - ROOM 010
351 WEST CENTER
CEDAR CITY, UT 84720

SAMPLE NUMBER : K0890514

COST : 154.20

TIME COLLECTED : 9:00 AM

DATE COLLECTED : 5-25-89

DATE RECIVED : 30-MAY-1989

DATE COMPLETED : 5-JUL-1989

DATE SENT : 7-6-89

INVOICE NUMBER : G-K0890514

COLLECTOR : DAVE HARTSHORN

SITE LOCATION : JOY SPRING

SEND RESULTS TO : JUMBO MINING COMPANY
P.O. BOX 999
DELTA, UT 84624

ALL RESULTS IN MILLIGRAMS/LITER (ppm)

ANIONS CATIONS CATIONS GEN PRAM OXYGEN CHECKS

188.4 BICAR
< 0.05 Fe-T
< 0.01 Pb

* 579.0 Cl

0.008 As 44.6 Mg

< 0.1 Ba * 0.060 Mn

0.20 FLUOR <0.001 Hg 7.7 PH

1.63 NO3 <0.002 Cd 30. K 0.56 SURF

191.0 Ca <0.005 Se

<0.005 Ag

< 0.01 Cr 336.0 Na

1428. TDS

0.02 Cu 0.26 Zn 0.20 TURBI

142.0 SO4

NOTES :

BRENT ROSE

5/3, 89

STEVEN E. CLYDE
ATTORNEY AT LAW

JULIE - SEC.

200 AMERICAN SAVINGS PLAZA
77 WEST SECOND SOUTH
SALT LAKE CITY, UTAH 84101

TELEPHONE
(801) 322-2516

6305 FERN SPRING COVE
AUSTIN, TEXAS 78730

TO Mr. Don A. Ostler
Utah Water Pol Control Committee
Department of Health
Salt Lake City, Utah 84116-0690
P.O. Box 16690

FROM JUMBO MINING COMPANY
6305 FERN SPRING COVE
AUSTIN, TEXAS 78730

TO Mr. ~~Don A. Ostler~~ DAVE HARTSHORN
Jumbo Mining Company
P.O. Box 999, Delta, Ut 84624

FROM JUMBO MINING COMPANY
6305 FERN SPRING COVE
AUSTIN, TEXAS 78730

TO Mr. Roger Foisey
Central Utah Dept. of Health
201 E, 500 North
Richfield, Utah 84701

FROM JUMBO MINING COMPANY
6305 FERN SPRING COVE
AUSTIN, TEXAS 78730

TO Mr. Bruce Hall
~~Don A. Ostler~~
CENTRAL UTAH DISTRICT HEALTH DEPT
146 N. MAIN ST
Nephi, Utah 84648

1
OF Lyn Menlove
Utah Air Quality Control
PHONE AREA CODE NUMBER EXTENSION
801 - 538-6108

United States Department of the Interior
Bureau Of Land Management
House Range Resource Area
15 East 500 North
P.O. Box 778
Fillmore, Ut. 84631
Tony MANZANARES
F. Rex ROWLEY

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
RICHFIELD DISTRICT OFFICE
150 EAST 900 NORTH
RICHFIELD, UTAH 84701

JERRY W. GOODMAN
DISTRICT MANAGER

801-538-1015
FRED NELSON
ATTORNEY GENERAL
OFFICE
236 STATE CAPITOL
SALT LAKE CITY, UTAH
84114